Mississippi River/Gulf of Mexico
Watershed Nutrient Task Force

Reassessment of Point Source Nutrient Mass Loadings to the Mississippi River Basin

November, 2006

Table of Contents

1. Introduction

The Mississippi and Atchafalaya River Basin, referred to together in this report as the Mississippi River Basin (MRB), drains 41 percent of the contiguous United States. Together, these two rivers account for 90 percent of the fresh water inflow and a substantial amount of the total nutrient load entering the Gulf of Mexico. As part of an integrated assessment of hypoxia in the northern Gulf of Mexico, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Task Force) is investigating the impact of point source nutrient loadings from dischargers in the MRB that contribute to the total nutrient load reaching the Gulf of Mexico. An initial assessment of point source nutrient loading in the MRB was completed in 1998 (Tetra Tech 1998), and this report presents results of a nutrient point source mass loading reassessment begun in 2005. Point source nutrient loading data were derived from USEPA's Permit Compliance System (PCS) database. This current point source reassessment estimates the annual nutrient mass load for total nitrogen (TN), total phosphorus (TP), and biochemical oxygen demand (BOD) based on conditions as of 2004.

This report is organized with the results and discussion presented first, followed by more detailed descriptions of the data and methodology implemented in the reassessment analysis.

2. Results

2.1 Loadings of Nitrogen, Phosphorus, and Biochemical Oxygen Demand

The results of this point source nutrient mass loading reassessment (annual loading calculated based on data reported in calendar year 2004) may be summarized as follows:

- Number of PCS permits selected/relevant to MRB loadings for Nitrogen = 31,817
- Number of PCS permits selected/relevant to MRB loadings for Phosphorus = 30,498
- Number of PCS permits selected/relevant to MRB loadings for BOD = 33,326

Based on the estimation procedures applied to the PCS data, the total annual loadings of nitrogen, phosphorus, and biochemical oxygen demand from the Mississippi River Basin are summarized in Table 1.

Table 1. Total annual point source loading estimates of nitrogen, phosphorus, and biochemical oxygen demand in the MRB.		
	Kilograms per day (kg/day)	Pounds per year (lb/yr)
Nitrogen	578,681 kg/day	465,736,936 lb/yr
Phosphorus	97,840 kg/day	78,744,078 lb/yr
Biochemical oxygen demand (BOD)	690,863 kg/day	556,023,814 lb/yr

Mass load contribution from sewage treatment plants (SIC=4952) compared to other industrial categories indicates that sewage treatment plants contribute approximately 64.1% of the total nitrogen load, about 65.7% of the total phosphorus load, and about 62.5% of the total load of BOD (Table 2).

Table 2. Total annual point source loading contribution of nitrogen, phosphorus, and BOD from sewage treatment plants vs. other sources in the MRB.		
	From Sewage Treatment Plants (SIC=4952)	From other Industrial Categories (SIC≠4952)
Nitrogen	370, 789 kg/day (298,420,257 lb/yr) 64.1% of total N mass load	207,892 kg/day (167,316,679 lb/yr) 35.9% of total N mass load
Phosphorus	64, 291 kg/day (51,743,004 lb/yr) 65.7% of total P mass load	33, 549 kg/day (27,001,074 lb/yr) 35.3% of total P mass load
BOD	431499 kg/day (347,281,183 lb/yr) 62.5% of total BOD mass load	259364 kg/day (208,742,631 lb/yr) 37.5% of total BOD mass load

The largest contributing sectors by SIC name of nitrogen, phosphorus, and BOD loadings to the MRB, other than sewage treatment plants, are presented in Tables 3 through 5. (Note: There may be slight variations in sums of total mass loading of TN, TP, and BOD in these tables due to number rounding in the calculation steps.)

Table 3. Percent contribution by Standard Industrial Classification for top 10 non-sewage treatment-plant contributors to MRB loadings of total nitrogen

	SIC code	SIC name	Total nitrogen load (kg/day)	Percent of total nitrogen load
	4952	SEWERAGE SYSTEMS	370,789	64.1%
1	2869	INDUST. ORGANIC CHEMICALS NEC	78,056	13.5%
2	2821	PLSTC MAT./SYN RESINS/NV ELAST	33,135	5.7%
3	0241	DAIRY FARMS	12,845	2.2%
4	0211	BEEF CATTLE FEEDLOTS	8,727	1.5%
5	1311	CRUDE PETROLEUM & NATURAL GAS	8,536	1.5%
6	4931	ELEC & OTHER SERVICES COMBINED	5,906	1.0%
7	2046	WET CORN MILLING	5,405	0.9%
8	2865	CYCLIC CRUDES INTERM., DYES	5,006	0.9%
9	4953	REFUSE SYSTEMS	4,356	0.8%
10	2621	PAPER MILLS	2,180	0.4%
	other	other	43,739	7.6%
		Total	578,681	100.0%

Table 4. Percent contribution by Standard Industrial Classification for top 10 non-sewage treatment plant contributors to MRB loadings of total phosphorus				
	SIC code	**SIC name**	**Total phosphorus load (kg/day)**	**Percent of total phosphorus load**
	4952	SEWERAGE SYSTEMS	64,291	65.7%
1	1311	CRUDE PETROLEUM & NATURAL GAS	5,333	5.5%
2	4931	ELEC & OTHER SERVICES COMBINED	3,679	3.8%
3	4953	REFUSE SYSTEMS	2,719	2.8%
4	2046	WET CORN MILLING	2,642	2.7%
5	2048	PREP FEEDS & INGRED FOR ANIMA	1,158	1.2%
6	1221	BITUMINOUS COAL & LIG, SURFACE	957	1.0%
7	2621	PAPER MILLS	889	0.9%
8	6515	OPER OF RES MOBILE HOME SITES	853	0.9%
9	5171	PETROLEUM BULK STATIONS & TERM	688	0.7%
10	2611	PULP MILLS	624	0.6%
	other	other	14,007	14.3%
		Total	97,840	100.0%

Table 5. Percent contribution by Standard Industrial Classification for top 10 non-sewage-treatment-plant contributors to MRB loadings of BOD				
	SIC code	**SIC name**	**Total BOD load (kg/day)**	**Percent of total BOD load**
	4952	SEWERAGE SYSTEMS	431,499	62.5%
1	2621	PAPER MILLS	43,944	6.4%
2	2611	PULP MILLS	41,942	6.1%
3	1311	CRUDE PETROLEUM & NATURAL GAS	18,210	2.6%
4	2631	PAPERBOARD MILLS	14,979	2.2%
5	2869	INDUST. ORGANIC CHEMICALS NEC	14,682	2.1%
6	4931	ELEC & OTHER SERVICES COMBINED	12,563	1.8%
7	4953	REFUSE SYSTEMS	9,581	1.4%
8	9711	NATIONAL SECURITY	5,164	0.7%
9	2046	WET CORN MILLING	4,440	0.6%
10	9999	NONCLASSIFIABLE ESTABLISHMENTS	3,824	0.6%
		other	90,035	13.0%
		Total	690,863	100%

Tables 6a-6c (and corresponding Figures 1-3) present the annual point source mass loading contributions by hydrologic region within the MRB for total nitrogen, total phosphorus, and biochemical oxygen demand. The "Unresolved Basin" row represents permits whose hydrologic region was not identified in the PCS database, and which could not be assigned to a hydrologic region because latitude and longitude data were missing for the permit and could not be accurately resolved from other address information from the permit.

Table 6a. Annual point source mass loading contributions by hydrologic region within the MRB for TN

2-digit HUC/Hydrologic Region	Number of permits (for N loading)	Nitrogen load (kg/day)	Percentage of total nitrogen load
05 Ohio	8881	152,982	26.4
06 Tennessee	1353	24,511	4.2
07 Upper Mississippi	4915	116,553	20.1
08 Lower Mississippi	6283	128,757	22.3
10 Missouri	6189	83,183	14.4
11 Arkansas-Red-White	3680	66,019	11.4
Unresolved Basin	516	6,667	1.2
Total	31,817	578,672	100.0

Note: HUC = hydrologic unit code

Figure 1. Annual point source mass loading contributions by hydrologic region within the MRB for TN.

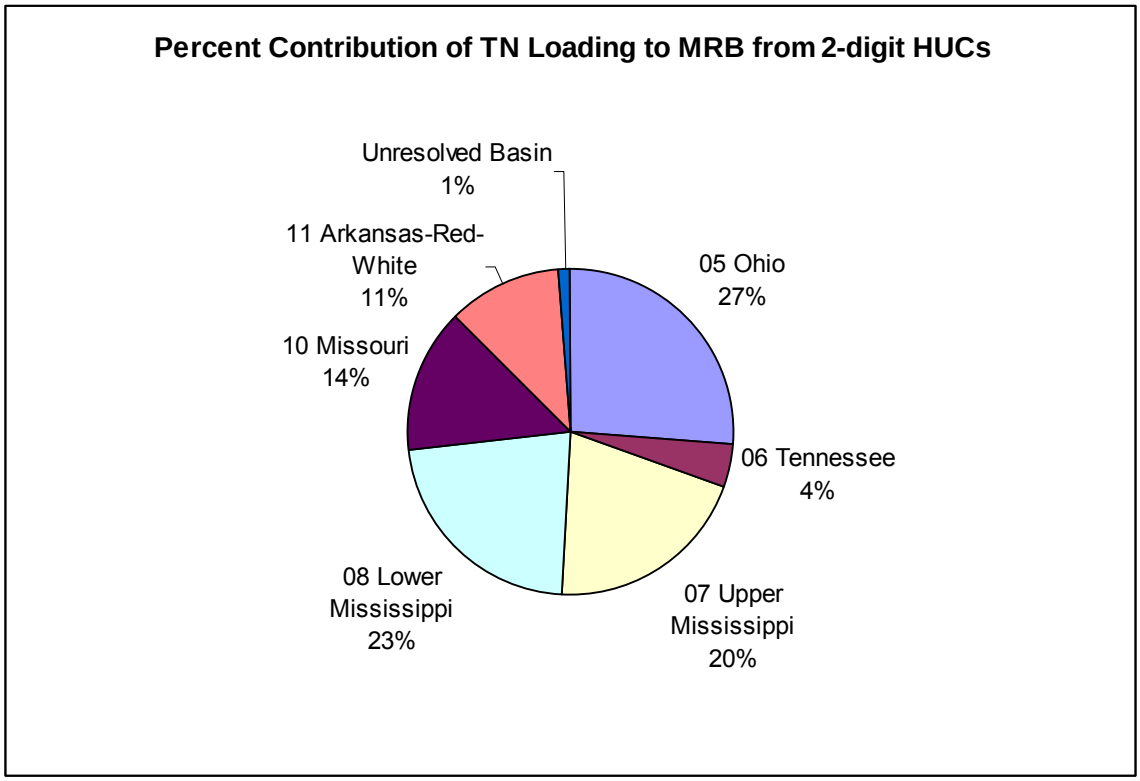


Table 6b. Annual point source mass loading contributions by hydrologic region within the MRB for TP			
2-digit HUC/Hydrologic Region	**Number of permits (for P loading)**	**Phosphorus load (kg/day)**	**Percentage of total phosphorus load**
05 Ohio	7960	21,013	21.5%
06 Tennessee	1248	5,898	6.0%
07 Upper Mississippi	4736	21,966	22.5%
08 Lower Mississippi	6329	14,411	14.7%
10 Missouri	6086	16,637	17.0%
11 Arkansas-Red-White	3630	14,338	14.7%
Unresolved Basin	509	3,575	3.7%
Total	30,498	97,838	100.0%

Figure 2. Annual point source mass loading contributions by hydrologic region within the MRB for TP.

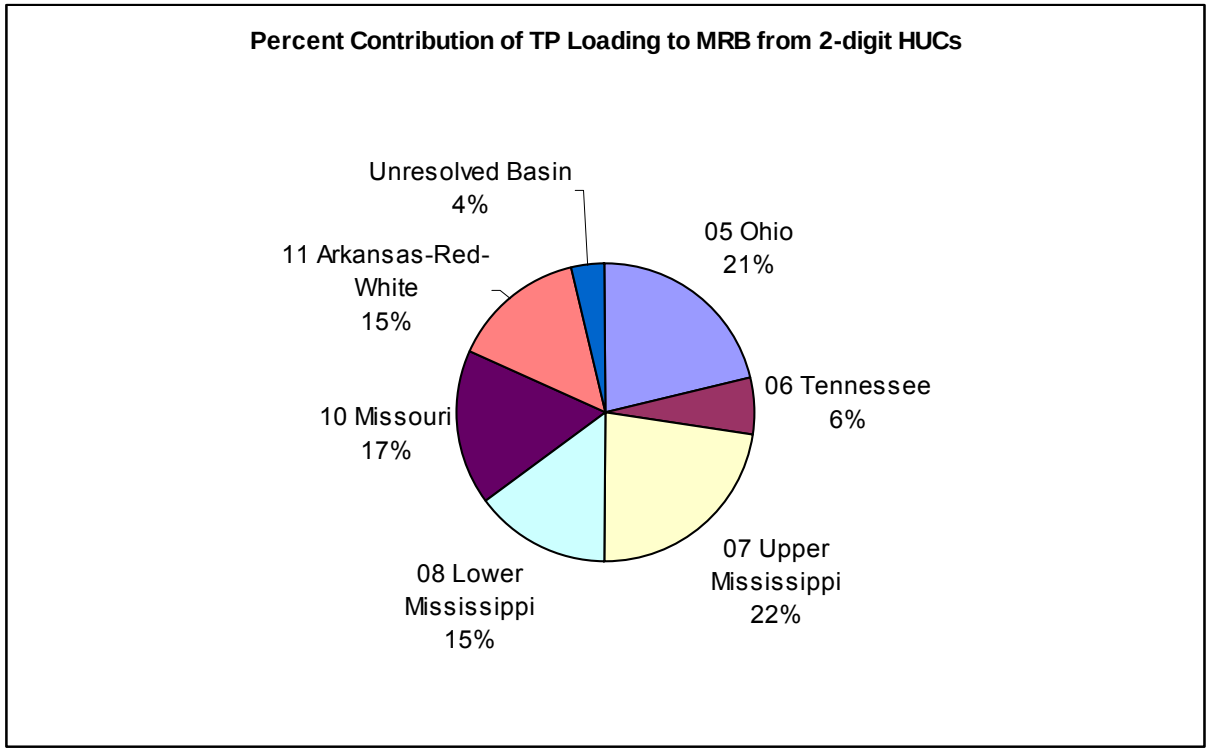
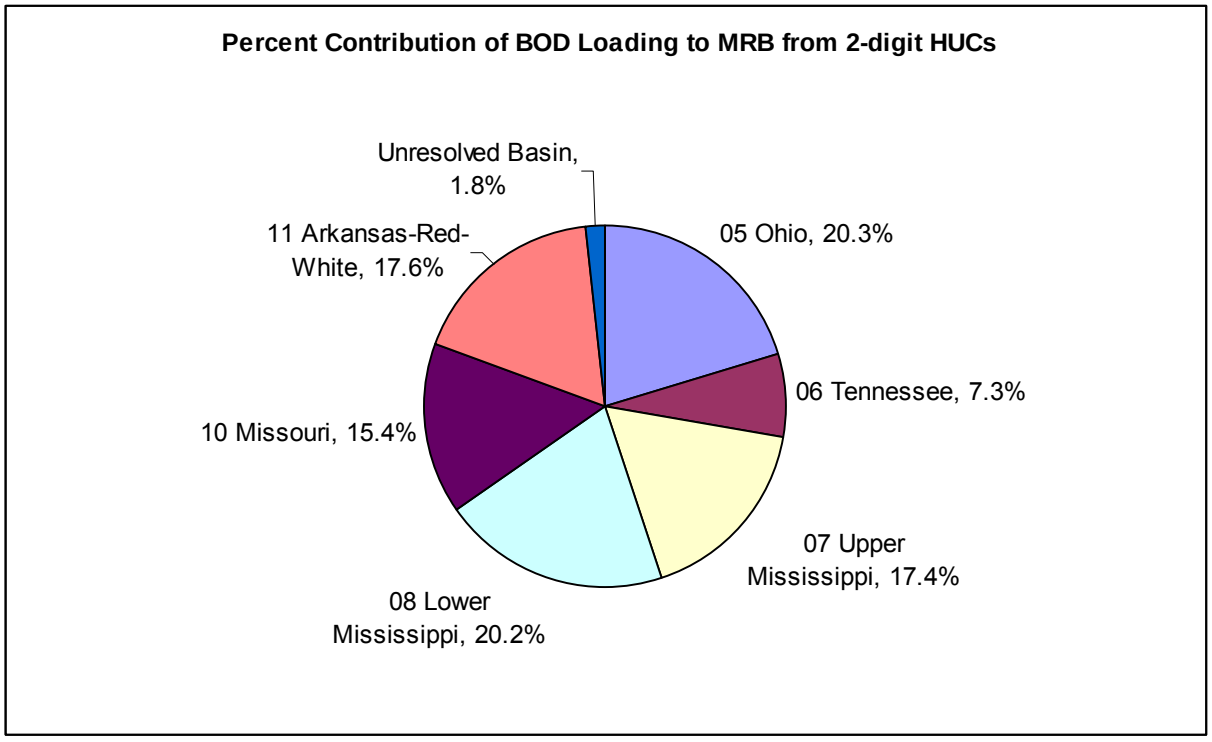


Table 6c. Annual point source mass loading contributions by hydrologic region within the MRB for BOD			
2-digit HUC/Hydrologic Region	**Number of Permits (for BOD loading)**	**BOD load (kg/day)**	**Percentage of Total BOD Load**
05 Ohio	9417	140,419	20.3%
06 Tennessee	1493	50,702	7.3%
07 Upper Mississippi	5031	120,212	17.4%
08 Lower Mississippi	6738	139,229	20.2%
10 Missouri	6251	106,572	15.4%
11 Arkansas-Red-White	3781	121,350	17.6%
Unresolved Basin	525	12,380	1.8%
Total	33,236	690,864	100.0%

Figure 3. Annual point source mass loading contributions by hydrologic region within the MRB for BOD.



2.2 Discussion

The estimated total MRB point source mass loadings based upon PCS data for total nitrogen (TN) and total phosphorus (TP) in the current reassessment are substantially lower than those estimated in the 1998 assessment (Tetra Tech 1998). More permitted discharges were considered in the mass loading calculations for this reassessment (TN: approximately 31,817 permits, TP: approximately 30, 498 permits) as compared with the previous assessment (approximately 11,500 "facilities" considered for TN and/or TP). Nevertheless, the estimated total mass loading for nitrogen has been found to be about 466 million pounds per year compared with 642 million pounds per year in 1998—about 73 percent of the previous estimate. The estimated total mass loading for phosphorus has been found to be about 79 million pounds per year compared with the previous estimate of about 133 million pounds per year—about 59 percent of the previous estimate (Table 7).

Table 7. Comparison of MRB point source nutrient loading analysis results between the 1998 assessment report vs. current assessment

	1998 Assessment (based on 1996 data)	2005-2006 Assessment (based on 2004 data)
Number of discharges counted in the analysis	11,500 facilities	31,817 permits (TN) 30498 permits (TP) 33,236 permits (BOD)
Total MRB estimated Nitrogen Load	642 million lb/yr	466 million lb/yr
Total MRB estimated Phosphorus Load	133 million lb/yr	79 million lb/yr
Total MRB estimated BOD Load	Not estimated	566 million lb/yr

Several possible explanations could explain the differences in TN and TP results between the 1998 and 2005 point source nutrient mass loading assessments. One explanation is the differences between the methods and procedures used in each assessment. For consistency when comparing results, the methodology used in this reassessment attempts to follow the same procedures used in 1998 to the extent possible; however, changes were made from the previous methods when such changes were likely to provide improvements in the accuracy of the results. For example, because of the more varied nature of data sources in the 1998 assessment (PCS supplemented with a variety of miscellaneous electronic and paper reports from state and USEPA regional offices), there were many approximations and assumptions built into the procedures at all levels (see, for example, the 1998 assessment's Appendix C, Instructions to Field Collectors of Data, regarding calculating average annual flow [Tetra Tech 1998]). In contrast, this reassessment relied almost entirely on PCS data, but several adjustment factors were also applied in an attempt to improve the applicability of literature estimated values for pollutant concentrations and facility flows not available through PCS (see Section 4 Methodology). In addition, typical pollutant concentration (TPC) values used as estimates in this reassessment had been updated for some industry categories since the 1998 report (1993 values [Pait et al. 1993] vs. 1999 values [Tetra Tech 1999]). In particular, TPC for phosphorus in sewage treatment plants was reduced for the secondary

treatment level from 7.0 mg/L in the 1993 tables to about 2.0 mg/L in the 1999 tables and for the tertiary treatment level from 3.5 mg/L in the 1993 tables to 0.8 mg/L in the 1999 tables. Finally, it is possible that with improvements in actual nutrient removal by dischargers, the data themselves represent lower nutrient content in effluents being discharged into the MRB between 1996 (data used in the 1998 assessment) and 2004 (data used for this reassessment).

3. Data Description

This effort at estimating point source nutrient mass loading to the Gulf of Mexico from the MRB relied primarily on data obtained from USEPA's PCS, which houses permitting and Discharge Monitoring Report (DMR) data on companies or facilities that have been issued National Pollutant Discharge Elimination System (NPDES) permits to discharge water into water bodies in the MRB. The 1998 assessment relied on data obtained from a variety of sources to supplement data obtained from PCS. Examples of such data sources include state and USEPA regional databases maintained independently of PCS, paper DMR reports in state files, and NPDES renewal applications in state and USEPA regional offices. For the current reassessment effort, it was assumed that data from the miscellaneous sources consulted in 1998 are now housed fairly reliably and comprehensively in PCS, and, that therefore, PCS data can provide the basis for a reasonable estimate of point source nutrient loading in the MRB.

The permits in PCS were screened and selected for applicability and relevance to this MRB point source nutrient loading reassessment based on the following criteria:

1. Geographic relevance to the MRB and Gulf of Mexico hypoxia; i.e., the permitted sources discharge into waters within the MRB.
2. Active within the selected time period of interest for this analysis (annual nutrient loadings for the period January-December 2004). Annual loadings were estimated for calendar year 2004.
3. For the calculation of mass loadings, the permits selected as described in 1. and 2. were evaluated based on:
   - Chemical relevance to nutrient mass loadings; i.e., permits with: numeric criteria or limits, or monitoring requirements for nutrient parameters (any forms of nitrogen or phosphorus, including ammonia) or biochemical oxygen demand (BOD), expressed as either concentration in discharge or loading in discharge (see Table 8 below),

   Or

   - Any/all SIC codes that had TPC values for the relevant parameters (Tetra Tech, 1999).

The mass loading calculation was not restricted to permits with numeric criteria or monitoring requirements for nutrient parameters and/or BOD. Section 4 (Methodology), outlines the calculation methods applied to the selected permits in detail.

The selection criteria, the chemical parameters evaluated, as well as the type of permits selected, are further described below.

3.1 Geographic Selection of PCS Permits

The geographic extent of point source nutrient mass loading for this analysis is defined as the Mississippi River Basin, composed of the six hydrologic regions (2-digit HUCs) identified in Figure 4.

Figure 4. Six hydrologic regions (2-digit HUCs) in the Mississippi River Basin.

USGS Code	Hydrologic Region
07	Upper Mississippi
10	Missouri
06	Tennessee
05	Ohio
11	Arkansas-Red-White
08	Lower Mississippi

The goal was to identify all potential point source discharges of nitrogen or phosphorus in the Mississippi River Basin System housed in the PCS database, as well as potential sources of oxygen-demand.

The first geographic screening steps for selecting PCS permits for this nutrient loading analysis were to:

- Exclude any permits from states entirely outside the MRB, and
- Include any permits from states entirely within the MRB.
- Include any permits from counties entirely within the MRB.

Next, geographic coordinate data for MRB permits in PCS, when available, were checked for accuracy by applying a GIS analysis to verify that latitude and longitude data accurately represented other Address Information available for the permit (for example, did not locate a facility with a permit ID from the state of MN in the middle of the Atlantic Ocean).

For permits whose geographic coordinate data were unresolved or questionable, and whose discharges were located in a state that is partially within the MRB, other location data were checked as follows:

- If the permit data does not identify the county in which the discharge is located, or the county is only partially in the MRB, then check Street Address, City, and any other Address data fields, using further analysis as described below.

A further analysis step was applied to reduce uncertainty in location by applying a geocoding process to the address information available for the permit. Locations were

geocoded with the EZ-Locate Geocoding Service (EZ-Locate Geocoding Service, 2006) provided by Tele Atlas, Inc. EZ-Locate is a geocoding service that provides real-time access to the Tele Atlas address and street database and geocoding technology. The EZ-Locate software generates latitude/longitude coordinates for an address record using the best available data in that record (street address, street, zip+2, 5-digit zip, and 3-digit zip, in that order). The more detailed the information available for an address record, the more precise the coordinates.

After applying this geocoding process, permit coordinates were further analyzed using a GIS methodology with respect to the boundaries of the MRB, and the following decision was taken:

- Include the permit if the coordinates of the discharge Address (location of the discharge and not the facility mailing address) lies within 2 miles of the boundary of the MRB.

The results of the geocoding report, summarizing the number of coordinates resolved by the type of address information matched are provided below:

Match Type	Number of permits	Percent of total (%)
0	908	3.09%
1	8,037	27.35%
2	1,667	5.67%
3	1,248	4.25%
4	16,807	57.18%
5	724	2.46%
6	0	0%

Notes:
Match 0 = no match found
Match 1 = Match is an exact house number match within a single side of a single street block OR is a unique intersection
Match 2 = Match is to a single street block within +/- 100 house numbers of the input, but the correct side of street and correct placement within block are not known
Match 3 = Match is to a ZIP+2 vicinity
Match 4 = Match is to a 5-digit ZIP vicinity
Match 5 = Match is to a 3-digit ZIP vicinity
Match 6 = Match is to multiple street segments

The GIS analysis and screening provided the following count of permits included in the loading calculations:

31,301 out of 31,817 permits (98.4%) included in the TN loading calculation for the entire MRB had geographic coordinate data whose accuracy is resolved with high confidence while 516 permits (1.6%) are confirmed with reasonable confidence to be located within 2 miles of the MRB boundary based on non-coordinate location information.

29,989 out of 30,498 permits (98.3%) included in the TP loading calculation for the entire MRB had geographic coordinate data whose accuracy is resolved with high

confidence while 509 permits (1.7%) are confirmed with reasonable confidence to be located within the MRB or 2 miles of the MRB boundary based on non-coordinate location information.

31,711 out of 33,236 permits (98.4%) included in the BOD loading calculation for the entire MRB had geographic coordinate data whose accuracy is resolved with high confidence while 525 permits (1.6%) are confirmed with reasonable confidence to be located within the MRB or 2 miles of the MRB boundary based on non-coordinate location information.

3.2 Period of Record of PCS Permits

Data from calendar year 2004 were retrieved from PCS in November 2005 for this reassessment. Permits were included in the analysis if they were "Active" as of the November 2005 data retrieval. Annual loadings of nutrient data for calendar year 2004 were determined by running the Effluent Data Statistics (EDS) System retrieval option in PCS, specifically Option BS (USEPA 1995). Further description of the EDS retrieval and data processing routine is provided in Section 4 (Methodology) of this report.

3.3 Nutrient Loading Parameters

Data from calendar year 2004 for were retrieved from PCS in November 2005 for this reassessment. Permits were considered as having numeric nutrient limits when either concentration (minimum, average, or maximum) or loading (average or maximum) is limited with a number for at least one parameter in Table 8.

Table 8. Nutrient Parameters Considered in PCS permits

N/P	General Grouping	Units	Species measured	Param ID	Description
N	TN	mg/L	as N	00600	NITROGEN, TOTAL (AS N)
N	Ammonia	lb/day/cfs	as NH_3+NH_4	00151	NITROGEN, AMMONIA PER CFS OF STREAMFL
N	Ammonia	%	as NH_3+NH_4	00175	NITROGEN, AMMONIA, PERCENT REMOVAL
N	Ammonia	mg/L	as N	00608	NITROGEN, AMMONIA DISSOLVED
N	Ammonia	mg/L	as N	00609	AMMONIA NITROGEN, TOTAL, (AS N) 30DAY
N	Ammonia	mg/L	as N	00610	NITROGEN, AMMONIA TOTAL (AS N)
N	Ammonia	mg/L	as N	00612	NITROGEN, AMMONIA, TOT UNIONIZED (AS N)
N	Ammonia	mg/L calc	as NH_3	00619	AMMONIA, UNIONIZED
N	Ammonia	mg/L	as NH_3	34726	NITROGEN, AMMONIA, TOTAL (AS NH3)
N	Ammonia	mg/L	as NH_3	51085	NITROGEN, AMONIA (NH3-N), (WATER)
N	Ammonia	ug/L	as N	61574	AMMONIA (AS N) + UNIONIZED AMMONIA
N	Ammonia	mg/L	as nh4	71845	NITROGEN, AMMONIA TOTAL (AS NH4)
N	Ammonia	mg/L	as NH_3+NH_4	82230	AMMONIA & AMMONIUM-TOTAL
N	Inorganic	mg/L	as N	00640	NITROGEN,INORGANIC TOTAL
N	N oxides	mg/L	as N	82385	NITROGEN OXIDES (AS N)
N	Nitrate	mg/L	as N	00618	NITROGEN, NITRATE DISSOLVED
N	Nitrate	mg/L	as N	00620	NITROGEN, NITRATE TOTAL (AS N)
N	Nitrate	mg/kg	mg/kg-N dry wgt	00621	NITRATE NITROGEN, DRY WEIGHT
N	Nitrate		as NO3	51086	NITROGEN, NITRATE (N03), (WATER)
N	Nitrate	mg/L	as NO3	71850	NITROGEN, NITRATE TOTAL (AS NO3)
N	Nitrite	mg/L	as N	00613	NITRITE NITROGEN, DISSOLVED (AS N)
N	Nitrite	mg/L	as N	00615	NITROGEN, NITRITE TOTAL (AS N)
N	Nitrite	mg/L	as NO_2	71855	NITROGEN, NITRITE TOTAL (AS NO2)
N	Nitrite plus Nitrate	mg/L	as N	00630	NITRITE PLUS NITRATE TOTAL 1 DET. (AS N)
N	Nitrite plus Nitrate	mg/L	as N	00631	NITRITE PLUS NITRATE DISSOLVED 1 DET.
N	Organic	mg/L	as N	00605	NITROGEN, ORGANIC TOTAL (AS N)
N	Organic	mg/L	as N	00607	NITROGEN, ORGANIC, DISSOLVED (AS N)
N	TKN	mg/L	as N	00625	NITROGEN, KJELDAHL TOTAL (AS N)
N	TKN	mg/L		49579	NITROGEN, TOTAL KJELDAHL

N/P	General Grouping	Units	Species measured	Param ID	Description
N	TKN	mg/L	as N	51087	NITROGEN, KJELDAHL, TOTAL (TKN) (WATER)
N	TKN	%		81393	NITROGEN, TOTAL KJELDAHL, % REMOVAL
P	TP	mg/L	as P	00665	PHOSPHORUS, TOTAL (AS P)
P	TP	mg/L		00442	PHOSPHOROUS, TOTAL ELEMENTAL
P	TP	ug/L	as P	00662	PHOSPHOROUS, TOTAL RECOVERABLE
P	TP	mg/L	as po4	71888	PHOSPHORUS,TOTAL SOLUBLE (AS PO4)
P	TP	%		81012	PHOSPHORUS, TOTAL PERCENT REMOVAL
P	Organic	mg/L	as P	00670	PHOSPHOROUS, TOTAL ORGANIC (AS P)
P	Ortho	mg/L	as po4	00660	PHOSPHATE, ORTHO (AS PO4)
P	Ortho	mg/L	as P	00671	PHOSPHATE, DISSOLVED/ORTHOPHOSPHATE (AS P)
P	Ortho		as P	04175	PHOSPHATE, ORTHO (AS P)
P	P diss	mg/L	as P	00666	PHOSPHORUS, DISSOLVED
P	phosphate	mg/L	as po4	00650	PHOSPHATE, TOTAL (AS PO4)
P	phosphate	mg/L		00653	PHOSPHATE TOTAL SOLUBLE
P	phosphate	mg/L	as P	70505	PHOSPHATE, TOTAL COLOR. METHOD (AS P
P	TP in phosphate	mg/L	as P	70507	PHOSPHOROUS, IN TOTAL ORTHOPHOSPHATE
BOD		mg/L		00310	BOD, 5-DAY (20 DEG. C)
BOD		mg/L		80082	BOD, CARBONACEOUS05 DAY (20 DEG. C)

3.4 PCS Permit Types

Data from PCS were included in the point source nutrient loading analysis for Permit Types if they contained nutrient-related impacts. Specifically, permits were included for the permit types of Standard, General, Unpermitted, State Individual or Statewide. Tables 9a-9c summarize the evaluation of permits for inclusion based on Permit Type. Table 9d lists the permit types excluded in this assessment as well as the reason for exclusion.

Table 9a. Permit Types included in mass loading calculations for TN, TP, and BOD in the MRB

PTYP	Permit type description	Number of permits	Percentage of all permits
(none)	STANDARD	20,170	60.6
G	GENERAL	9,931	29.8
U	UNPERMITTED	2,754	8.3
J	STATE INDVL	442	1.3
H	STATEWIDE	5	0.0

Table 9b. Mass Loading of TN, TP, and BOD by Permit Type in the MRB				
PTYP	**Permit type description**	**Load of TN (kg/day)**	**Load of TP (kg/day)**	**Load of BOD (kg/day)**
(none)	STANDARD	521,663	88,837	611,202
G	GENERAL	35,293	7,124	66,637
U	UNPERMITTED	20,393	1,584	11,486
J	STATE INDVL	1,317	293	1,505
H	STATEWIDE	14	1	34

Table 9c. Percent contribution of Mass Loading by Permit Type in the MRB				
PTYP	**Permit Type Description**	**TN**	**TP**	**BOD**
(none)	STANDARD	90.1%	90.8%	88.5%
G	GENERAL	6.1%	7.3%	9.6%
U	UNPERMITTED	3.5%	1.6%	1.7%
J	STATE INDVL	0.2%	0.3%	0.2%
H	STATEWIDE	0.0%	0.0%	0.0%

Table 9d. Permit types specifically excluded from the point source nutrient loading analysis.		
Permit type	**Permit type description**	**Comment**
A	AFO/CAFO	Animal agriculture; non-point source
P	PRETREATER	Discharge to a treatment plant and not directly to receiving waters
R S	STORM WATER STORMWATER	Stormwater general Stormwater individual Intermittent and flashy nature of flow (storm flushes that can be interrupted by long periods of no discharge) requires different analysis method, and these Stormwater sources may be more appropriately considered under non-point source analyses.

Table 10 presents a further breakdown of permit types used in the analysis (all Active), indicating the number of (a) permits with numeric nutrient limits, (b) permits with monitoring requirements for nutrient parameters, and (c) other permits, as well as their Major or Minor classification. (Note: A *Major facility* is any facility classified as such by the USEPA Regional Administrator, or the Regional Administrator in conjunction with the State Director for approved state programs. In general, municipal dischargers of at least 1 million gallons per day are considered Majors, but there is no single criterion for designating industrial facilities as Major.)

Figures 4 and 5 show the number of facilities in the MRB by state that have monitoring requirements for TN and TP respectively, and represent the actual status of monitoring in those states.

Table 10. Permit types used in the analysis, by Major or Minor permit type, showing how many permits have numeric nutrient criteria or limits, or have monitoring requirements for at least one nutrient-related parameter presented in Table 5.			
	Number of permits with numeric nutrient criteria	Number of permits with monitoring requirements	Other
Major	1,500	282	497
Minor	5,532	1,801	23,690

Figure 4. Status of Actual Outflow Monitoring for TN in MRB States (2006)

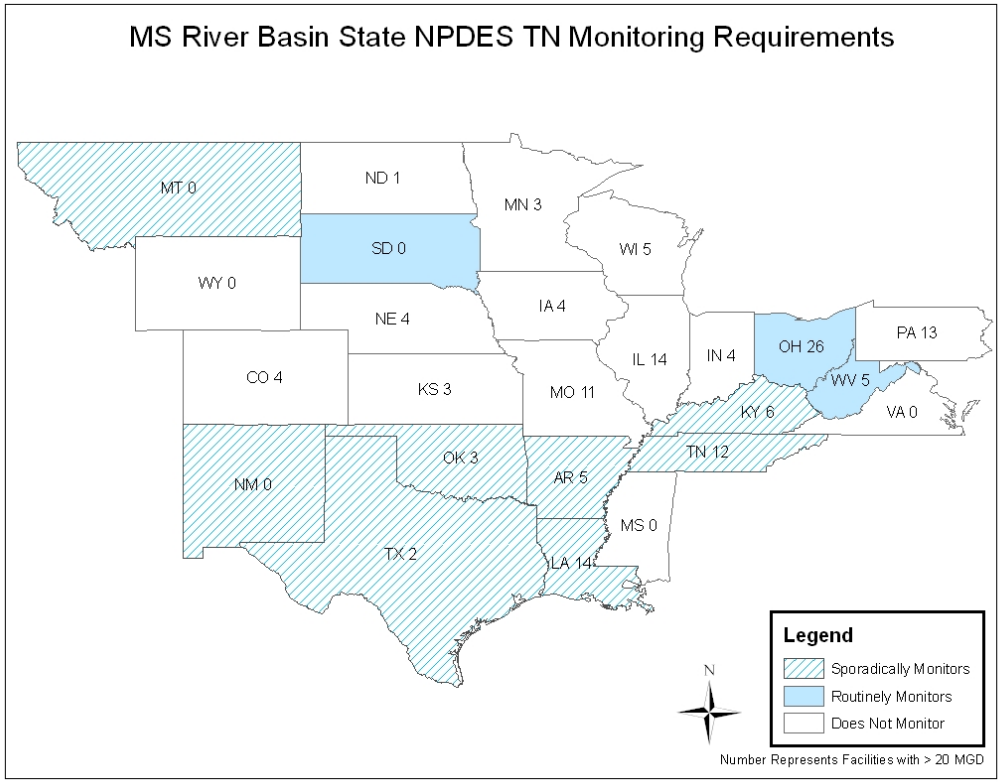
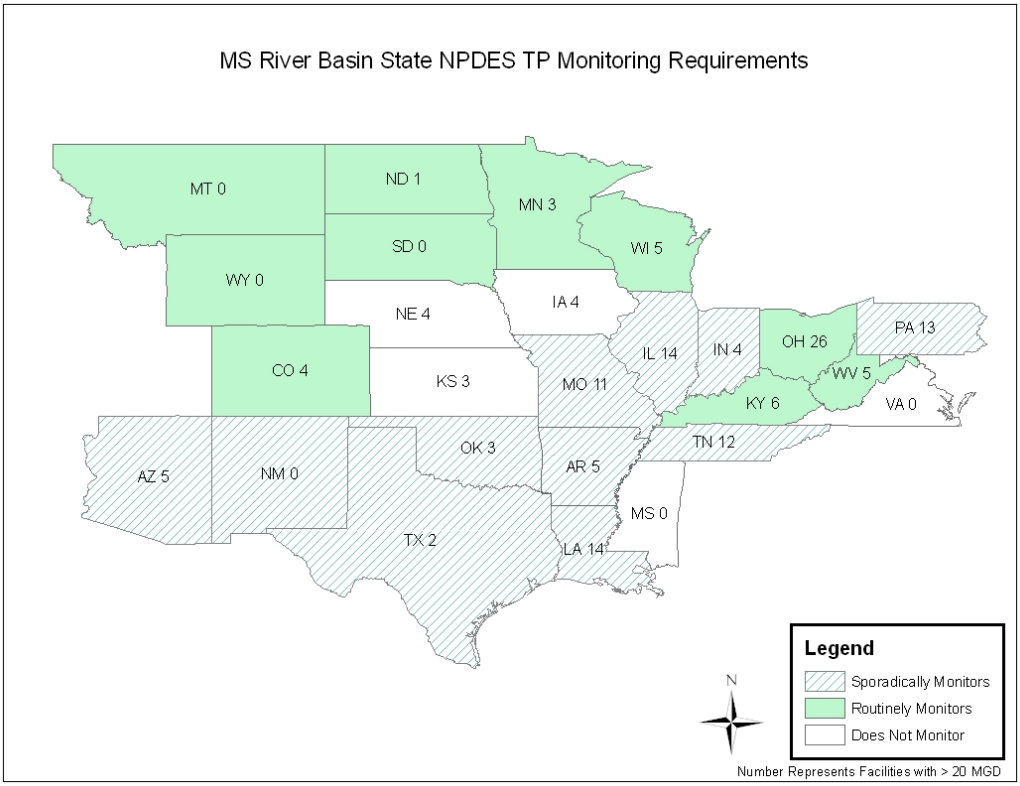


Figure 5. Status of Actual Outflow Monitoring for TP in MRB States (2006)



4. Methodology

Calendar year 2004 data for this point source nutrient mass loading reassessment were retrieved from PCS in November 2005. Permits were considered as having numeric nutrient limits when either concentration (minimum, average, or maximum) or quantity (average or maximum) is limited with a number for at least one parameter in Table 8 in Section 3 of this report.

4.1. Data Processing and Quality Assurance

4.1.1 Units Consistency

Data were processed to ensure the consistency of units. All concentration units were converted to milligrams per liter (mg/L) and all flow units were converted to million gallons per day (MGD). Unit conversions were performed throughout all loadings calculations to ensure that final loadings were consistently reported in the standard units of kilograms per day (kg/day), and then converted to pounds per year (lb/yr).

4.1.2 Parameter Species

Data for nutrient parameters that measured for and reported a value as something other than "as N" or "as P" needed to be converted to "as N" or "as P" values. Table 11 lists the conversion factors used for this step (Tetra Tech 1998).

Table 11. Conversion factors for converting reported nutrient parameters to "as N" or "as P"

If reported	Multiply by	To get
as NO_3	0.23	as N
as NO_2	0.30	as N
as NH_3	0.82	as N
as NH_4	0.78	as N
as PO_4	0.33	as P

4.2 Nutrient Load Determinations

As a result of variations in the types of data available or reported in PCS, five different methods were developed for determining point source nutrient mass loadings from PCS point sources in the MRB. Each of these methods was applied to as many of the PCS permits as possible. Results from different methods were then evaluated for each permit. The final loading for each permit was selected from the method determined the most applicable, based on the data available from the permit compared with data inputs required by the analytical method. Each of these methods and steps is explained further in the this section.

Tables 12a and 12b provide a summary description of each of the analysis methods, along with the numbers of permits and proportional loadings contribution accepted under each method to include in the final MRB nutrient loading estimate and the final BOD loading estimate respectively.

Loadings for both nitrogen and phosphorus were always taken from the same method for each permit. In Table 12a, note that for some permits, either N or P species were sometimes not available, hence the total number of permits for calculating N loading (31,817) and the total number of permits for calculating P loading (30,498) is less than the total number for calculating N and/or P (32,416).

4.3 PCS Loadings Retrieval

Data for this point source nutrient mass loading reassessment were retrieved from PCS in November 2005. Annual loadings of nutrient data for permit year 2004 were determined by running the Effluent Data Statistics (EDS) System retrieval option in PCS, specifically Option BS (USEPA 1995). A general overview of EDS, provided by USEPA (1997) states:

> "The EDS process starts by extracting the reported DMR [Discharge Monitoring Report] data that have been entered into PCS. These data are then processed through a software program to add the flow data to each record so that loadings can be calculated using flow and concentration whenever mass loading data have not been reported for a monitoring period. The effluent data are then converted into PCS standard units since the data can be reported in various units. After the data have been converted, they are processed by the EDS routines to calculate mass load totals."

Loadings values using EDS were determined for whichever nutrient pollutant species data were available for the selected permit (see Table 8 *[Nutrient Parameters considered in PCS Permits]*). In some cases, PCS permits are written in terms of mass loadings, rather than concentrations, and in these cases the loadings were directly available from PCS.

For permits with numeric nutrient criteria or limits for nitrogen or phosphorus species other than total nitrogen (TN) or total phosphorus (TP), constituent nitrogen or phosphorus species were summed, where available, to approximate TN or TP as follows.

- Using all available N species, sum components measured "as N" (or, converted to "as N" as explained in Section 4.1.2) to get TN (Tt 1998) using the formulas:
  - $TN = TKN + NO_3 + NO_2$ (usually very little NO_2), if all of these parameters are not null in PCS, else
  - $TN = NH_4 + NH_3 +$ organic $N + NO_3 + NO_2$, if all of these parameters are not null in PCS (note: TKN = NH4+ NH3 + organic N), else
  - If any permit data are not available for any of the required forms of nitrogen, the summed N is only a partial (incomplete) sum and not actually (true) TN. Find the sum, and flag the result as partial N, and then determine the most appropriate nitrogen loading value to use from these

permits by comparing with results obtained from other methods explained below.

- For phosphorus, most limits were reported as TP (only rarely as orthophosphate) and no substitute summation steps were applied.

Nitrogen and phosphorus loadings resulting from these EDS procedures were determined to be the best estimate for 1,246 of the 32,416 permits used in the final MRB nutrient loading estimation (Table 12a).

BOD loadings resulting from these EDS procedures were determined to be the best estimate for 8,261 of the 33,236 permits used in the final MRB loading estimation (Table 12b).

4.4 Loading Estimation Using TPCs and CWNS

As described above, EDS calculates mass loading data for a pollutant using flow data and concentration data retrieved in PCS. For permits or facilities where either flow data or concentration data, or both, were missing, other estimation procedures were necessary. In addition, results obtained from the following estimation methods were compared with EDS results to determine which estimate was the most reasonable (conservative) estimate to use in this MRB point source nutrient mass loading reassessment. Estimation methods also provided results for comparison with results obtained when complete TN or TP summed values were not available from the EDS method described above in section 4.3.

Estimated concentration data for all permits, whether loadings were calculated using EDS or not, were obtained from Typical Pollutant Concentration (TPC) values as developed by NOAA (Pait et al. 1993) and updated by USEPA (Tetra Tech 1999). TPC tables of values have been developed based on Standard Industrial Classification (SIC) codes. For sewage treatment plants (SIC=4952), the TPC table values vary by level of treatment, but level of treatment is not indicated in PCS. Therefore, the Clean Watersheds Needs Survey (CWNS) database (USEPA 2004) was consulted to obtain information pertaining to level of treatment. This level of treatment information provided confirmation of the most applicable TPC value to select for use in the loading estimation analysis for sewage treatment plants whose nutrient concentration data were missing from PCS, and this step was added as an update to the steps followed in the 1998 assessment (Tetra Tech 1998). TPC values for other industrial categories (SIC≠4952) were taken from the TPC tables as published (Tetra Tech 1999).

Discharge flows also were estimated for all permits, when possible. Several methods were employed depending on (1) availability of data from a source other than PCS, or (2) industrial categories of the permits whose flow data were missing. The preferred source for missing flow data was the Clean Watersheds Needs Survey (CWNS) database (USEPA 2004), from which any available 2004 existing facility flows were obtained for MRB NPDES permits, for any categories of permits available in the CWNS database.

Nitrogen and phosphorus mass loadings based on TPC estimated concentrations and CWNS database estimated flows were determined to be the best estimate for 6,907 of the 32,416 permits used in the final MRB nutrient loading estimation (Table 12a).

BOD mass loadings based on TPC estimated concentrations and CWNS database estimated flows were determined to be the best estimate for 2,769 of the 33,236 permits used in the final MRB loading estimation (Table 12b).

4.5 Loading Estimation Using TPCs and Adjusted Design Flow: Sewage Treatment Plants

Actual facility flow was estimated based on the design flow listed in the permit data, to supplement the dataset for permits whose actual or existing flows were not available from PCS or from the CWNS databases. Different estimating procedures were applied to sewage treatment plant permits (SIC=4952) compared to those used for other permits (SIC≠4952). The first step in estimating a flow for sewage treatment plant permits for which flow data were unavailable from both PCS and the CWNS database was to calculate a ratio between *existing flow* and *present design flow* for all treatment plants (SIC=4952) whose data were available for both of those fields. This ratio was calculated for all such treatment plants in the entire CWNS database throughout the United States, and for all such treatment plants located in the MRB, and it was found to be a fairly stable ratio of 0.72. Then, this ratio was multiplied by the design flow value for sewage treatment plant permits for which existing or actual flow data were unavailable, resulting in an estimated adjusted facility flow. The estimated nutrient loading was calculated from estimated pollutant concentration (TPCs) and estimated facility flow using the following formula (including the 3.785 L/gallon units conversion factor):

$$\text{Load (kg/day)} = \text{Design flow (MGD)} \times 0.72 \times \text{TPC (mg/L)} \times 3.785 \text{ L/gallon}$$

4.6 Loading Estimation Using TPCs and Adjusted Design Flow: Non Sewage Treatment Plants

For permits other than treatment plants (SIC≠4952), the estimated adjusted flow value was determined by multiplying the permit's design flow by two variables obtained from the TPC tables according to SIC code: (1) the SIC *p*-factor, a ratio of process flow vs. total flow, and (2) the days per year of operation, divided by 365, resulting in a proportion of the year during which flow is discharged. This step is believed to be an update to the 1998 point source nutrient mass loading assessment (Tetra Tech 1998).

Under this method, the estimated nutrient loading was calculated from estimated pollutant concentration and estimated facility flow using the following formula:

$$\text{Load (kg/day)} = \text{design flow (MGD)} \times p\text{-factor} \times ((\text{operation days})/365) \times \text{TPC (mg/L)} \times 3.785 \text{ L/gallon}$$

Nitrogen and phosphorus mass loadings based on TPC estimated concentrations and estimated flows (adjusted design flow) for both sewage treatment plants and for non-sewage-treatment-plants were determined to be the best estimate for 12,918 of the 32,416 permits used in the final MRB nutrient loading estimation (Table 12a).

BOD mass loadings based on TPC estimated concentrations and estimated flows (adjusted design flow) for sewage treatment plants and for non-sewage-treatment-plants were determined to be the best estimate for 10,780 of the 33,236 permits used in the final MRB loading estimation (Table 12b).

4.7 Loading Estimation Using TPCs and Adjusted TFV

Finally, for a small number of permits for which facility flow and design flow were not provided in PCS or the CWNS database, an additional estimation method was employed. It was assumed that the discharge from sewage treatment plants with missing design flow and facility flow data would likely be less than 1 MGD, because it would be illegal for sewage treatment plants of greater discharge to fail to report their flow values to PCS. An estimation coefficient to apply to this final category of sewage treatment plant permits with missing design flow and facility flow data was determined by the following method:

- First, for all Major and Minor PCS permits with design flow data, the design flow was multiplied by two variables obtained from the TPC tables according to SIC code: (1) the SIC code *p*-factor, a ratio of process flow vs. total flow, and (2) the days per year of operation, divided by 365, resulting in a proportion of the year during which flow is discharged. The resulting adjusted design flows were averaged. The resulting average adjusted design flow for this comprehensive set was determined to be 1 MGD.
- Then, the same procedure was performed on the subset of only Minor permits with design flow data.
- The ratio between the two above-described adjusted average design flows results in a coefficient of 0.28.
- Typical Flow Values (TFV) developed by NOAA (1993) were applied according to SIC code to determine estimated nutrient loadings under this method. The design flow coefficient of 0.28 was applied to TFVs for Minor permits. Nutrient loadings were estimated for permits in this final subset, where (1) design flow and existing flow are unavailable, AND either (2a) facility types are Major, OR (2b) nutrient limits are included in permits.
    - The nutrient loading for Major permits in this final subset is found without applying the 0.28 coefficient, using the following formula:

      Load (kg/day) = TFV (MGD) × TPC (mg/L) × 3.785 L/gallon

    - The nutrient loading for Minor permits in this final subset is found by applying the 0.28 coefficient, using the following formula:

Load (kg/day) = TFV (MGD) × 0.28 × TPC (mg/L) × 3.785 L/gallon

Nitrogen and phosphorus mass loadings based on TPC estimated concentrations and estimated flows (adjusted TFVs) were determined to be the best estimate for 11,343 of the 32,416 permits used in the final MRB nutrient loading estimation (Table 12a).

BOD mass loadings based on TPC estimated concentrations and estimated flows (adjusted Typical Flow Values) were determined to be the best estimate for 11,426 of the 33,236 permits used in the final MRB loading estimation (Table 12b).

Tables 12a. and 12b. presents a summary description of the various methods used to derive individual permit nutrient loadings and resulting estimates of the total nitrogen and phosphorus loadings in the Mississippi River Basin.

Table 12a. (TN and TP)
Note: estimation values are in order of decreasing confidence (increased estimation error) from top to bottom of the table.

	Method	Source of Pollutant Concen-tration Value	Soure of Discharge Flow Value	SIC Codes	Formula for Load Calculations	Number of Permits	Percent Contribution to Total Estimated MRB Nutrient Mass Load	
							Nitrogen	Phosphorus
1a	EDS Retrieval	PCS Database	PCS Database	Any	EDS Routines [see Note (A)]	1,248 for 1a+1b	11.1%	14.1%
1b	EDS Retrieval	PCS Database	PCS Database	Any	EDS Routines [see Note (B)]	1,248 for 1a+1b		
2	Estimation	TPC	CWNS existing flow	Any	Load (kg/day) = CWNS flow (MGD) × TPC (mg/L) × 3.785 L/gallon	6,907	45.2%	44.9%
3	Estimation	TPC	Design flow adjusted by coefficient = 0.72	4952 only	Load (kg/day) = Design flow (MGD) × 0.72 × TPC (mg/L) × 3.785 L/gallon	12,918 for rows 3+4	34.3%	33.9%
4	Estimation	TPC	Design flow adjusted by p-factor & operation days	Any except 4952	Load (kg/day) = Design flow (MGD) × p-factor × ((operation days)/365) × TPC (mg/L) × 3.785 L/gallon	12,918 for rows 3+4		
5	Estimation	TPC	No design flow or actual flow; TFV adjusted by design flow coefficient = 0.28	Any	**Minor**: Load (kg/day) = TFV (MGD) x 0.28 × TPC (mg/L) × 3.785 L/gallon **Major**: Load (kg/day) = TFV (MGD) x TPC (mg/L) × 3.785 L/gallon	11,343	9.4%	7.0%
Totals						32,416	Nitrogen 578,681 kg/day (465,736,936 lb/yr) 100%	Phosphorus 97,840 kg/day (78,744,078 lb/yr) 100%

Notes:
(A) TN & TP estimations are complete, either directly from TN & TP permit parameters, or complete sums (true total nitrogen or true total phosphorus) from component forms of nitrogen, or as direct loadings data from PCS permits.
(B) EDS summed N is partial, and either EDS sums are greater than results from other methods, or there are insufficient input data to estimate from other methods.

Table 12b. BOD
Note: estimation values are in order of decreasing confidence (increased estimation error) from top to bottom of the table.

	Method	Source of Pollutant Concen-tration Value	Source of Discharge Flow Value	SIC Codes	Formula for Load Calculations	Number of Permits	Percent Contribution to Total Estimated MRB BOD Mass Load BOD
1a	EDS Retrieval	PCS Database	PCS Database	Any	EDS Routines	8,261	62%
2	Estimation	TPC	CWNS existing flow	Any	Load (kg/day) = CWNS flow (MGD) × TPC (mg/L) × 3.785 L/gallon	2,769	9.2%
3	Estimation	TPC	Design flow adjusted by coefficient = 0.72	4952 only	Load (kg/day) = Design flow (MGD) × 0.72 × TPC (mg/L) × 3.785 L/gallon	10,780 for rows 3+4	22.8%
4	Estimation	TPC	Design flow adjusted by p-factor & operation days	Any except 4952	Load (kg/day) = Design flow (MGD) × p-factor × ((operation days)/365) × TPC (mg/L) × 3.785 L/gallon	10, 780 for rows 3+4	
5	Estimation	TPC	No design flow or actual flow; TFV adjusted by design flow coefficient = 0.28	Any	**Minor**: Load (kg/day) = TFV (MGD) x 0.28 × TPC (mg/L) × 3.785 L/gallon **Major**: Load (kg/day) = TFV (MGD) x TPC (mg/L) × 3.785 L/gallon	11,426	6%
Totals						33,236	BOD 690,862 kg/day (556,023,814 lb/yr) 100%
Notes:							

5. Changes to the 1998 Assessment

Changes to the 1998 point source nutrient mass loading assessment have been described throughout this report and are summarized here for reference.

- Data sources: PCS herein vs. variety of sources to supplement PCS in 1998
- 2004 annual loadings vs. 1996 loadings
- Added information about biological oxygen demand (BOD) loadings
- Excluded Hydrologic Region for Souris-Red-Rainy because it drains north to Canada and not to the Gulf of Mexico (erroneous contributions of only 0.4 percent of nitrogen total load and 0.3 percent of phosphorus total load reported in 1998 results).
- Went through an accurate geographic analysis and geocoding processing to verify location of permits in the MRB or within 2 miles of the MRB. Used address information to assign coordinates (with different levels of confidence) to facilities to assign them within 2 miles of the MRB, then applied geographic analysis to locate facilities by 2-digit HUCs within the MRB. The geocoding process applied to the permit address information reduced the number of facilities which were located in the MRB based on address information other than lat/long.
- TPC values updated to 1999 values were available for some SIC codes.
- Consulted CWNS database to verify which treatment level was applied to SIC 4952 permits, which provided the most applicable TPC value to use as a concentration estimate.
- Consulted CWNS database to provide existing flow values when values were missing from PCS.
- Typical Flow Values were adjusted by various methods (e.g., SIC p-factor, days of operation, design flow coefficient) in this reassessment, compared with unknown adjustment in 1998 assessment (details not documented in 1998 report)
- Results: This assessment considered larger number of permits to calculate mass loadings of TN, TP, and BOD vs. 11,500 "facilities" in 1998.
- Results: Compare results to 1998 Tables 1 and 2 totals; lower loading estimate in this reassessment. Possible reasons:
    - This reassessment used updated TPC values (Tetra Tech 1999) that were lower, especially for phosphorus in sewage treatment plants (e.g., TPC for phosphorus in sewage treatment plants was reduced for the secondary treatment level from 7.0 mg/L in the 1993 tables to about 2.0 mg/L in the 1999 tables and for the tertiary treatment level from 3.5 mg/L in the 1993 tables to 0.8 mg/L in the 1999 tables.)
    - Improvements in nutrient removal during treatment in sewage treatment plants have resulted in lower DMR values in PCS for 2004 as compared with 1996.

6. Acronyms and Abbreviations

BOD	Biochemical oxygen demand
CWNS	Clean Water Needs Survey
DO	Dissolved oxygen
DMR	Discharge Monitoring Report
EDS	Effluent Data Statistics
EPA	Environmental Protection Agency (U.S.)
GIS	Geographic Information System
HUC	Hydrologic unit code
mg/L	Milligrams per Liter
MGD	Million Gallons per Day
MRB	Mississippi River Basin
N	Nitrogen
NCPDI	National Coastal Pollutant Discharge Inventory
NH_3	Ammonia (un-ionized)
NH_4	Ammonium ion
NO_2	Nitrite
NO_3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
P	Phosphorus
PCS	Permit Compliance System
SAB	Science Advisory Board
SIC	Standard Industrial Classification
TFV	Typical Facility Flow Value
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TON	Total organic nitrogen
TP	Total phosphorus
TPC	Typical pollutant concentration
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geologic Survey

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